

# Microwave Nondestructive Evaluation (MNDE)

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# In the beginning . . .

There was corrosion detection

- SMRC wins 1999 Phase I SBIR program to prove concept of detecting corrosion under paint on (then) conventional metallic aircraft structure

Microwave Corrosion Detector (MCD)  
Circa 2003

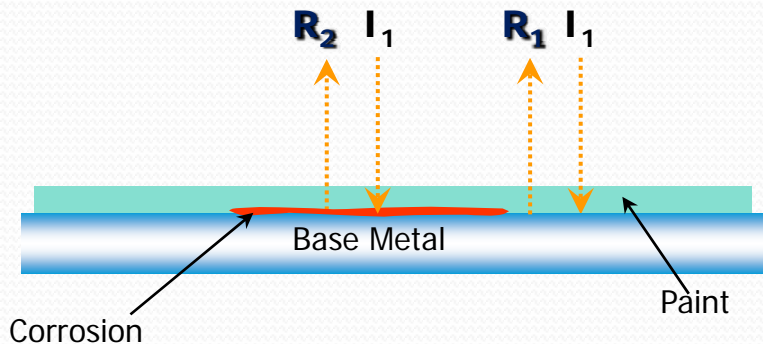
- 10 Beta units built and field tested
- Sensitive to onset levels of corrosion



# Detecting Corrosion with Microwaves

## Early Onset

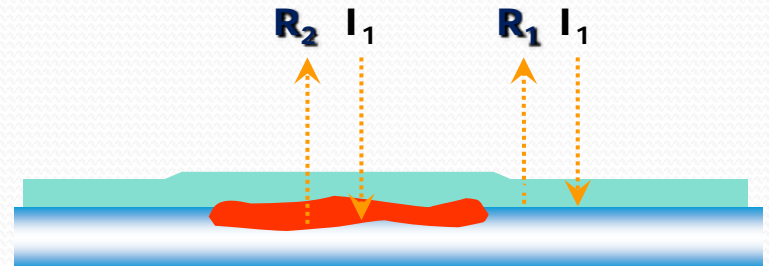
*Detecting dielectric contribution from oxides*



*$R_2 \neq R_1$  due to change in dielectric signature*

## Advanced Corrosion

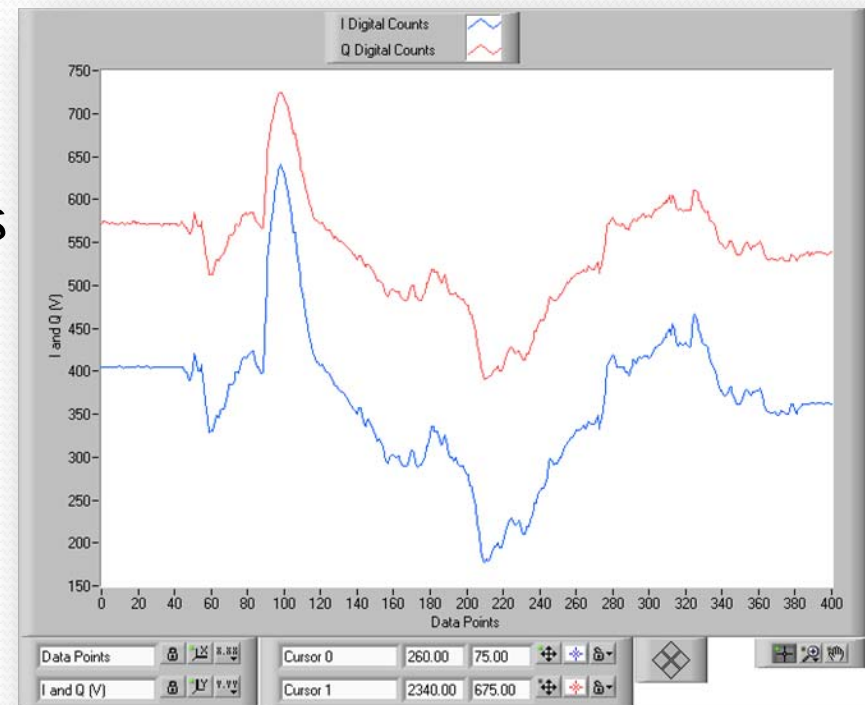
*Combination: dielectric and signal path to base metal*



*$R_2 \neq R_1$  due to change in dielectric signature and distance to base metal*

# From Door Openers to Corrosion Detectors

- Microwave transceiver operating in near field of target
  - COTS Doppler radar for automatic door opener sensors
- Schottky diodes sense reflected  $\mu$ wave energy components
- I and Q components digitized
- “Fingerprint” of reflected signal analyzed
- Corrosion/No-Corrosion decision



# A Funny Thing Happened on the Way to Corrosion Detection . . .

2001:

We make some bone-headed rookie assumptions that led us down a blind alley.

- **The BAD news:**
  - We can't tell the difference between extra coats of paint and corrosion
- **The GOOD news:**
  - Microwaves are very sensitive to differences in coating thickness
  - With math and motion we can eliminate the masking effects of variable coating thickness

Voila!

**Microwave corrosion detection works!**

(Sound of one hand clapping)

*“So what did you do with the coating thickness info?”*



# The F-35 Microwave NDE Era Begins

Jan 2003:

- Microwave Corrosion Detector introduced at LMA Ft. Worth
  - Stacey Luker, Robert Trice, Scott Fetter et al in attendance
- JSF team cool to corrosion detection, but . . .
- *We discover that (near field) microwave radiation penetrates specialty coatings*
  - On both metallic and composite substrates
- That opens the door to investigating numerous candidate applications for MNDE

Mid-2004:

- JPO lets first Phase III DO for SMRC

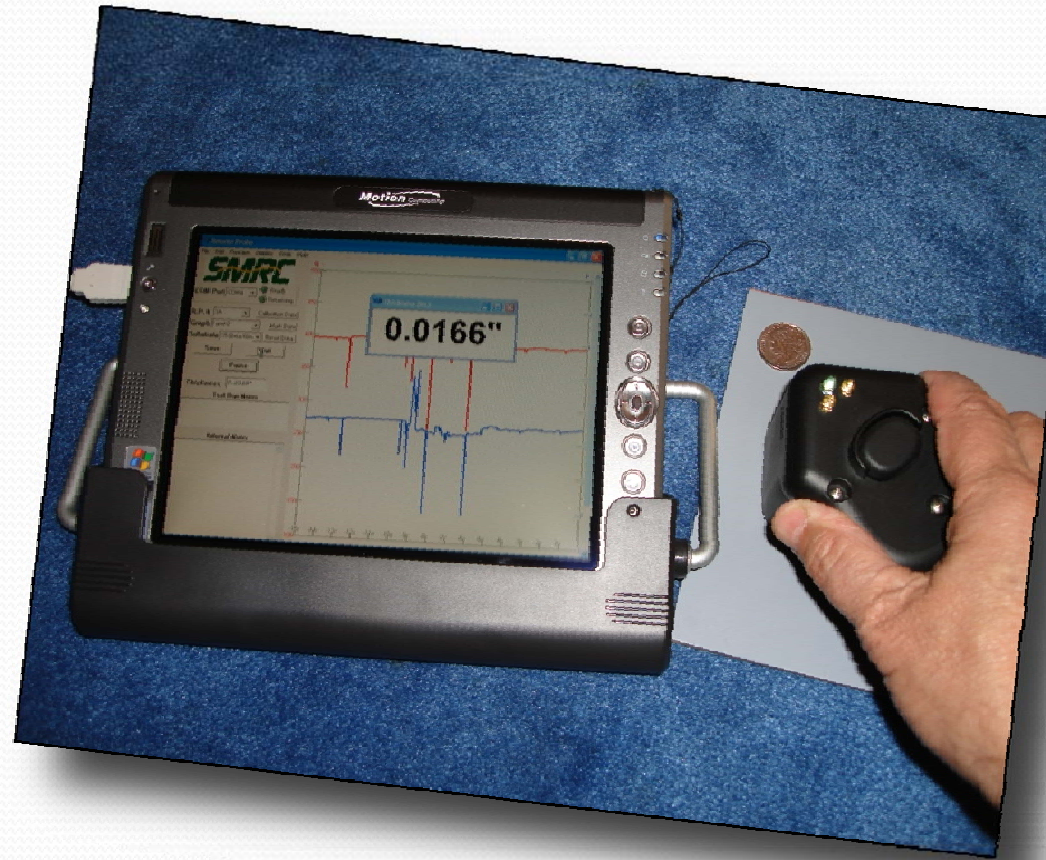


# Initial F-35 MNDE Applications

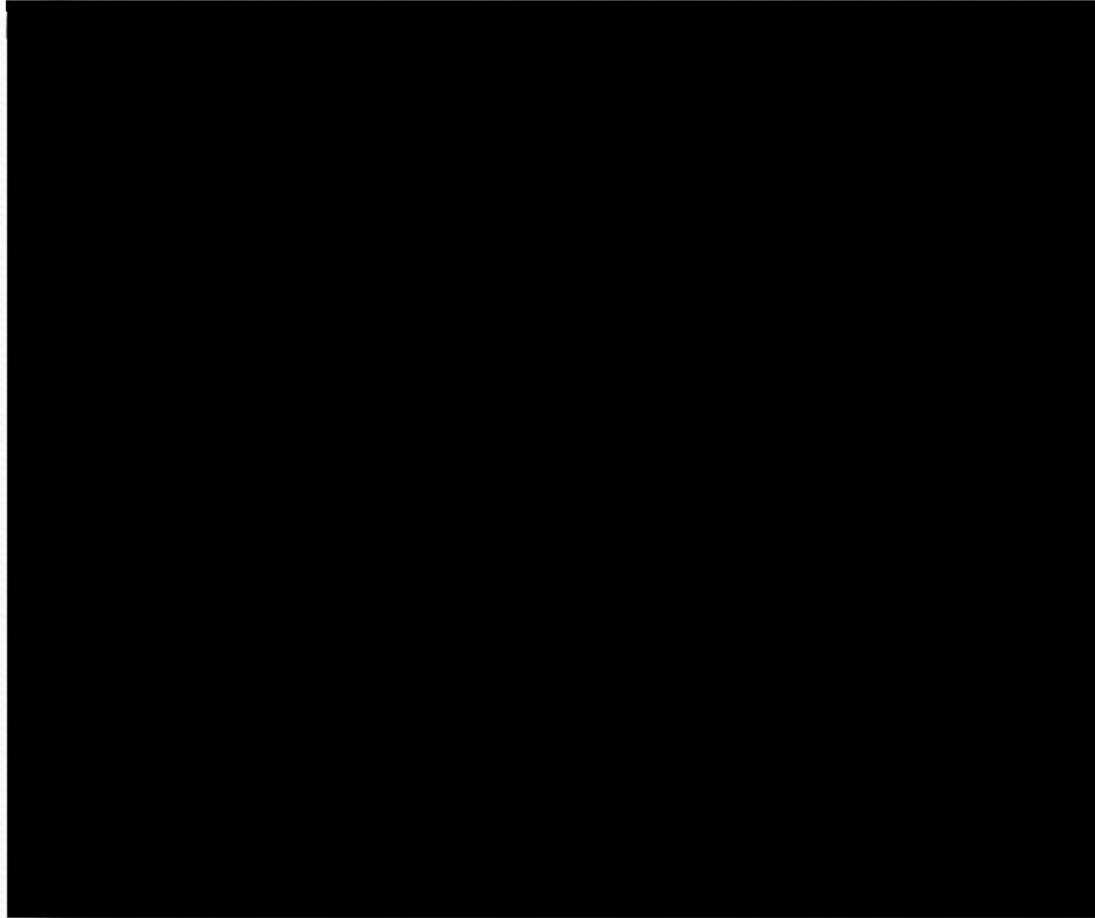
- Measure thicknesses of specialty coatings
  - Over metal
  - Over composites
    - With and without lightning strike
- Detect important features through coatings
  - Fasteners
  - Seams
  - Leaks
  - Corrosion

# The MNDE Toolkit™ is Born

A software-defined microwave NDE system capable of multiple inspection applications in a single handheld package

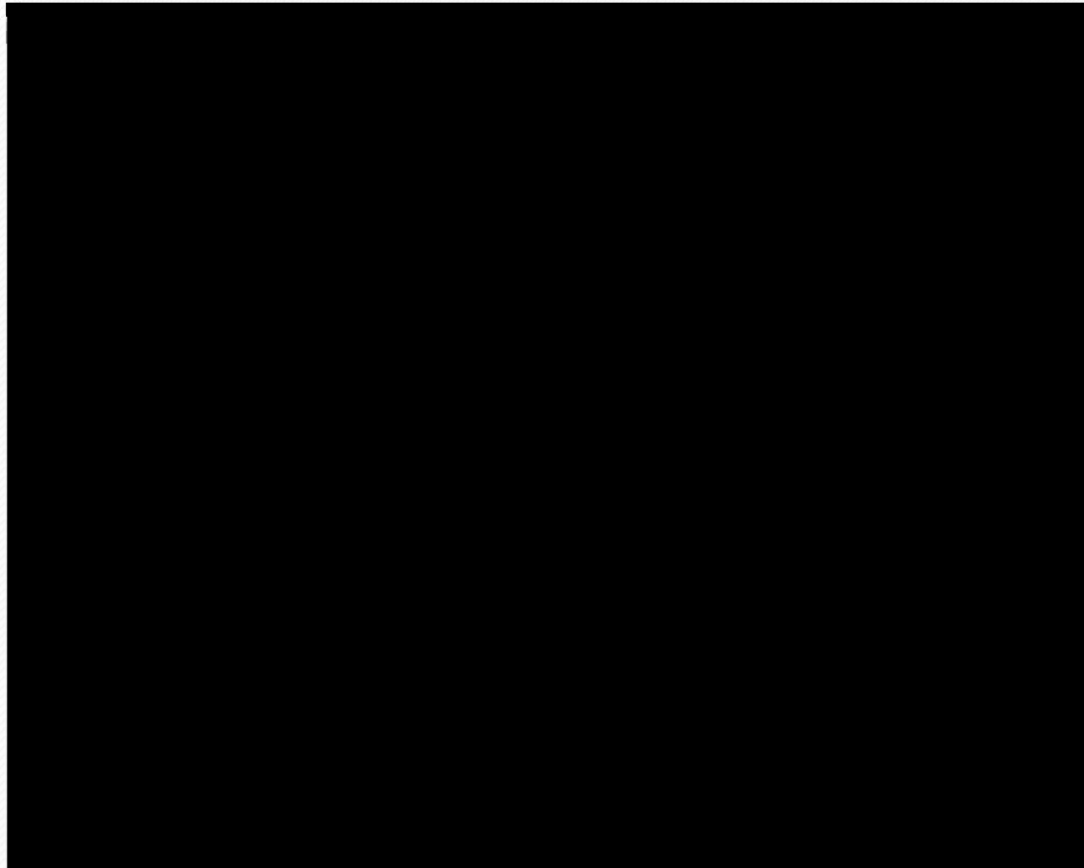


# Coating Thicknesses Measurement



*Remember the story of Goldilocks and the Three Bears?*

# Finding (and Marking) Fasteners with MNDE



# MNDE Toolkit Next Steps

- Mechanical/Electronic Design
  - Harden the Remote Probe for field (SE) use
    - Environmental
    - Explosion-proofing (Div2)
  - Improve marking mechanics
  - *Consider* redesigning into standalone system (connected to PC only for calibration)
- Software
  - Improve existing capabilities and add new ones
    - Improve fastener detection algorithms
    - Eliminate orientation effects in selected composites
    - Detect intrinsic heat damage in composites

# New MNDE Developments

- F-35 Final Finish Coating Thickness Measurement
  - Replace spray head with Microwave NDE/laser sensor suite
  - Check coating thicknesses at many points quickly using paint robot
  - NAVAIR (JSF) Phase II SBIR
    - In cooperation with NGC
- V-22 Erosion Coating Thickness Measurement
  - Leading edges of rotor blades (highly curved surfaces)
  - NAVAIR (V-22) Phase II SBIR
    - In cooperation with Bell Helicopter and Hontek



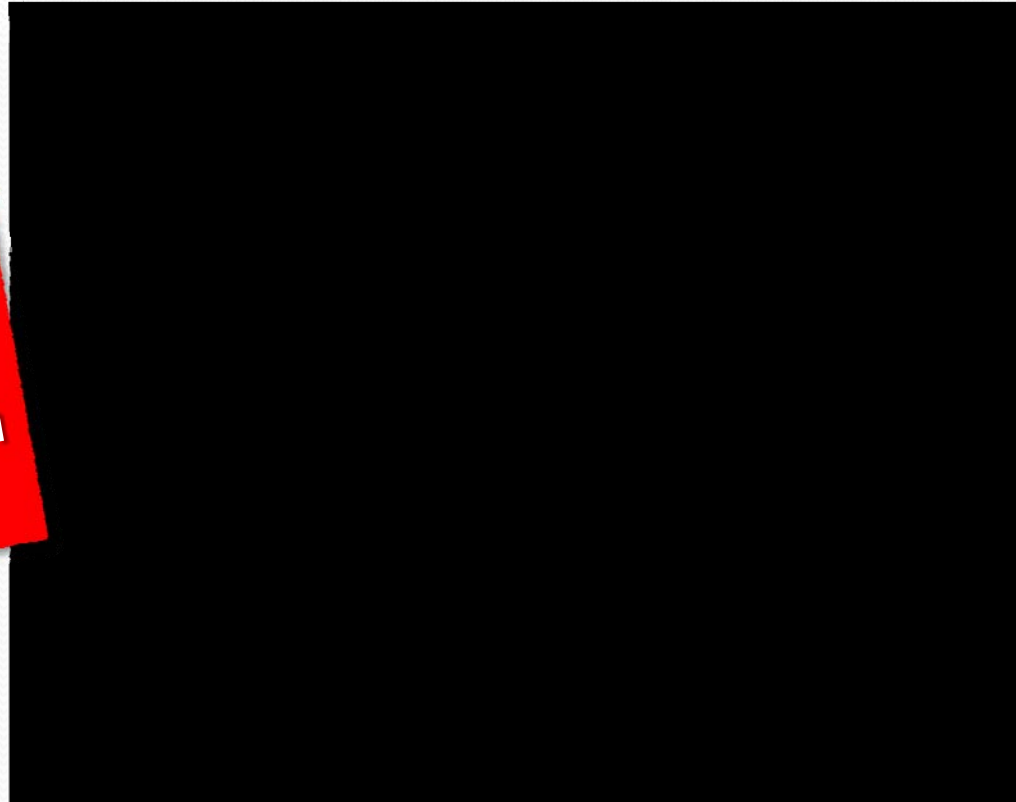
# MNDE Developments (Cont'd)

- F-35 Gap & Step Mismatch Measurement
  - Combination microwave/laser sensor suite
  - Measures through coatings and boots
  - Multiple gap types
    - With and without coatings
    - With and without boots
    - With and without lightning strike
- G-S measurements would allow significant workflow improvements in F-35 assembly
  - Lockheed ManTech Program



# Measuring Coatings in F-35 Final Finish

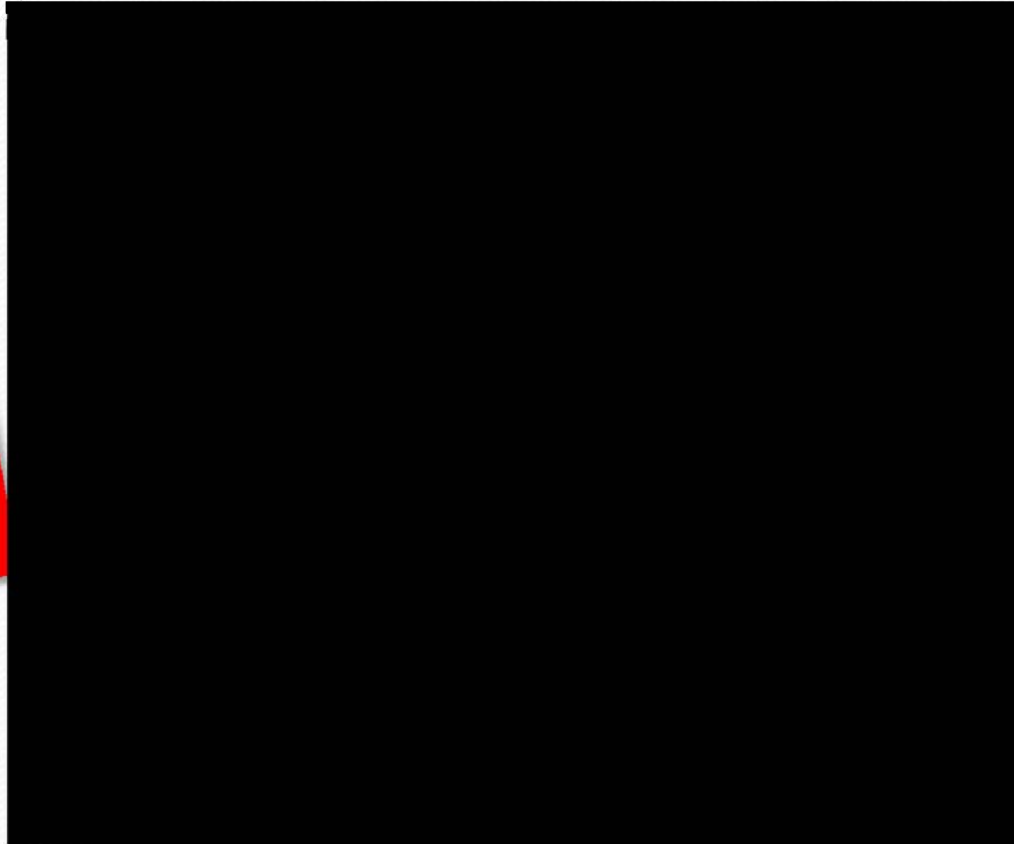
Phase II SBIR  
work in  
progress  
in cooperation  
with NGC



*End effector-mounted microwave/laser sensor  
head interchangeable with spray head*

# Measuring F-35 Gap and Step Mismatch

Early work in progress in cooperation with LMA



*MNDE gap-step measurement would allow significant efficiencies in F-35 production.*

# Since this is an ESTCP Workshop . . .

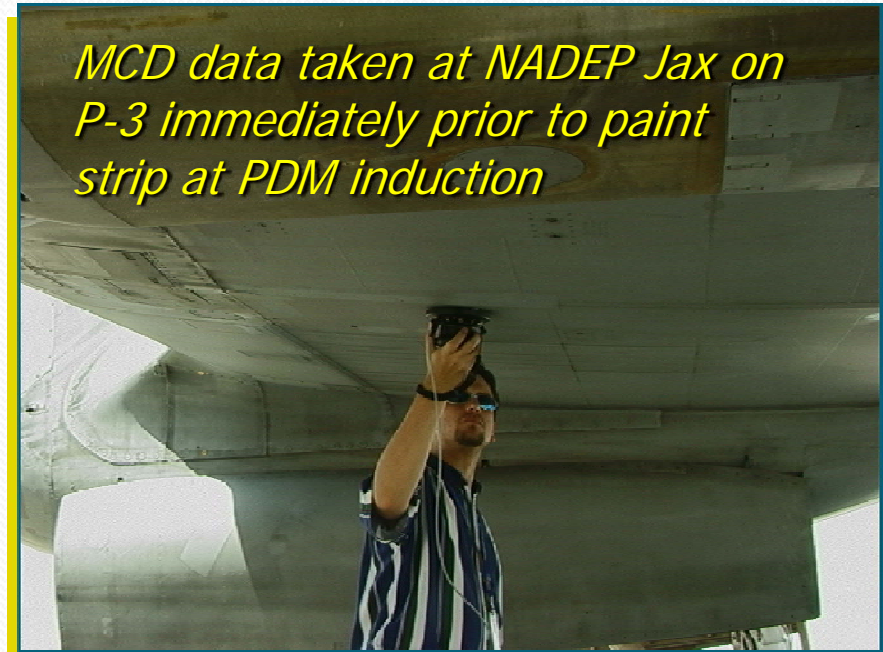
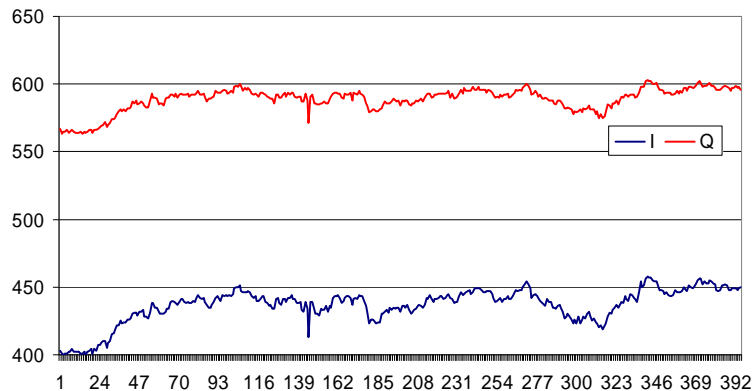
It's worth noting that corrosion detection isn't entirely passé.

- Even new advanced fighter aircraft corrode
  - And with specialty coatings it's even harder to detect . . .

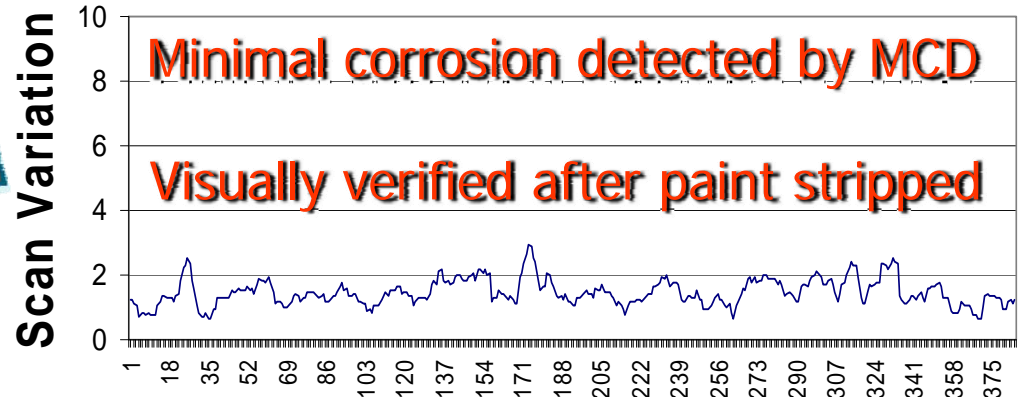
*But not with microwave.*

# An Early Lesson from the Field

Right wing centerline of plank 2  
over weapons pylon. Possible  
corrosion outboard of pylon  
(raw data)



Was it necessary to  
strip and repaint  
this P-3?





*Thank you for your attention!*

Questions?

*For more info*

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